TID-29094

Satellite Power System (SPS)

October 1978

Prepared for:

U.S. Department of Energy
Office of Energy Research
Satellite Power System Project Office

Under Contract No. EG. 77-C-01-4024

DOE/NASA

Satellite Power System
Concept Development
and
Evaluation Program

TID-29094
Distribution Category UC-11,
41,60,63,63a,63b,63c,63e,64,
66e,95f,97c

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Washington, D. C. 20545

Under Contract No. EG-77-C-01-4024

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WHITE PAPER

"An Overview of Prospective Organizational Structures in the Solar Power Satellite Field"

EXECUTIVE SUMMARY

The purpose of this White Paper is to identify and compare potential organizational options for a solar power satellite system (SPS).

This effort included a literature survey, interviews with acknowledged experts in the fields of organizational entities, space, solar energy, and the SPS concept, and an analysis of these inputs in order to identify the organizational alternatives and make judgments as to their feasibility to serve as patterns for a future SPS entity.

Selection and evaluation criteria were determined to include timeliness, reliability, and adequacy to contribute meaningfully to the U.S. supply; political feasibility (both national and international); and cost-effectiveness (including environmental and other external costs). Based on these criteria, four organizational alternatives appeared to offer reasonable promise as potential options for SPS. These included three domestic alternatives and one international alternative.

A large number of key issues emerged from the analysis as being factors which would influence the final selection process. Among these issues were a variety having to do with international law, international institutions, environmental controls, economics, operational flexibility, congressional policies, commercial-vs-governmental ownership, national dedication, and national and operational strategic issues.

Recommendations were made for further study on potential international institutional barriers, strategic safeguards, international acceptance of SPS, and factors likely to affect U.S. participation in various types of SPS organizations.

INTRODUCTION

In approaching the subject of feasible SPS organizational structures, it was found useful, first, to conduct a survey of any similar organizations which had been formed in recent years and which could serve as a parallel to any future SPS organization. Further, a second survey was then made which solicited expert opinions from those national figures who might give important insight into the potential suitability and effectiveness of possible structural alternatives for SPS, particularly in relation to U.S. political advantage, economic success, multinational participation, timely deployment, and potential

barriers. Finally, this White Paper was developed to set forth the results of these surveys, with an analysis of the political, environmental, economic, and safety aspects, as well as others, of each reasonably implementable potential structure.

From the very beginning of this effort, it was obvious that the comparatively recently formed entities, Comsat and INTELSAT, would be those with which the surveyed experts would logically compare a potential SPS system organization. Yet all agreed that the parallel was not at all exact, and, indeed, that the magnitude of the differences was sufficient to raise some doubt as to whether or not the final path of SPS would follow the Comsat/ INTELSAT pattern of organizational development.

In order to make a critical comparison between alternative SPS organizational structures in terms of political, international, environmental, and economic factors, it is necessary first to identify the major organizational options, and to select and formulate broad criteria by which such comparisons could be made. In this brief report, the comparisons are necessarily preliminary, leaving more detailed analysis to longer-term future studies. Present or recent organizations which parallel many of the future needs of SPS are identified as follows:

1. International agencies, such as CERN, INTELSAT, or ESA;

2. U.S. Government agencies or instrumentalities, such as the TVA or AEC; and

3. Domestic corporations, such as:

   a. Public (e.g., the U.S. Postal Service),

   b. Non-Profit (e.g., Blue Cross/Blue Shield),

   c. Business (e.g., ConEd), or

   d. Public-private (e.g., Comsat, Amtrak).

It is pointed out that the choice among these options need not be considered a permanent one. For example, a domestic organization could be formed which might later become international, or might associate itself with an international affiliate, perhaps to perform research or technological development or assessment. The present state of SPS technology and the large expenditures anticipated for SPS research and development indicate the desirability of multinational participation and cost-sharing. On the other hand, it is recognized that the transition of a national organization to international status may not be readily accepted by other countries, as the Comsat experience shows; and, in addition, the launching of a subsequent international organization tends to be slow and difficult, with a resulting loss of U.S. control (cf. the World Authority for the Seabed and INTELSAT).

The majority of the experts who were interviewed in the course of this study indicated their expectation that the SPS would probably (but by no means certainly) repeat the course of historical development followed by Comsat -- that is, that it would be organized as a U.S. business corporation, subject to Federal regulation and other controls, to be supplemented later by an international organization. (These people were regarded as experts because of their familiarity with space and energy technology, the SPS concept, and large organizational structures as well). On the other hand, a number of younger students of government subsequently interviewed for purposes of comparison seemed to favor setting up an international SPS organization, and to prefer U.S. Government agency participation, rather than a U.S. business corporation, to represent the United States within that framework. With all due respect to the latter group, they did not appear to be completely informed as to the rather complex organizational makeup of the Comsat and INTELSAT entities. They seemed, rather, to be reflecting the current spirit of the times, and this, of course, must also be of legitimate concern to any future SPS organizational planners.

ANALYSIS AND EVALUATION

1. Comparison Criteria

In undertaking to make independent preliminary comparisons among SPS organizational options, the preparers of this paper considered a substantial number (15 to 20) of candidate criteria. These were not mutually exclusive nor of equal importance. Some criteria were suggested by interviews, some by reading, and some by consideration of the problems likely to be faced by any major SPS effort. On analysis, some were seen to be corollaries or subsets of one or more others by a slightly broader formulation.

In the end, four tentative basic criteria were proposed for comparing and judging SPS organizational options. Although they interact substantially, these are believed to be distinct criteria, which can include, as corollaries or subsets, all the other candidate criteria which have been suggested. Their significance and relationships will now be briefly discussed.

The first criterion might be termed the adequate, timely, and reliable contribution to U.S. energy supply. This is regarded as the primary goal of an SPS program from the U.S. standpoint.

The present state of SPS technology, the cost and timing of the necessary R&D, and the technical (and the first-order economic) feasibility of the SPS may be included under this heading. Another factor is some present uncertainty regarding the SPS technology, which has not yet been totally demonstrated to be feasible technically, let alone economically -- unlike our comparative confidence in communication satellite technology in the early 1960's, when Comsat was formed. Technological uncertainty affects our national judgment as to whether or not to pursue even a limited scale prototype of an SPS system because we presently lack full confidence

that it can provide a reliable and commercial energy source. In addition, the distribution of any economic gain resulting from a deployed SPS system is a significant factor, especially for an international system, since it is not very likely that an internationally sponsored SPS hardware system would have a large portion of its electrical output beamed down to the United States, rather than to the other participating countries. Hence its adequacy to serve U.S. power needs may not be immediately realized.

Still another aspect of the contribution to U.S. energy supply is physical and strategic security. Because this subject has political implications, it will be discussed in the following Section.

The second criterion is domestic U.S. political feasibility. This factor is plainly critical to U.S. participation in any SPS organization, regardless of its form. Congressional authorization and funding, as well as Presidential and public support, are essential. In an interview conducted for this study, the opinion was volunteered that Congress would not authorize or "pour money into" an international organization which was not subject to substantial U.S. control. If this is an accurate political judgment, as it may well be, it points to a feasibility factor which may discriminate among different kinds of international SPS organizations, as well as between a domestic SPS organization and an international one.

Congress is likely to be influenced, in considering U.S. participation in an SPS program, by many factors including environmental compatibility, cost-effectiveness, the physical security and reliability of energy supply to the United States, pricing controls and service, U.S. energy export potential, the distribution of economic gain, and equitable and non-discriminatory access to the SPS system. Several of these matters are discussed elsewhere in this report. The problem of physical and strategic security calls for further comment here.

There are various technological means of interrupting or otherwise adversely affecting an SPS energy beam. For example, one or more satellites could be attacked with weapons and disabled, or an unauthorized command signal could shut off the transmitter. Appropriate safeguards must be provided from the early planning stages so that those who are expected to authorize the establishment of an SPS organization will have the confidence in its dependability necessary to proceed with its inauguration.

Many opinions will be offered, and national policies suggested, as to the reliability of relying upon SPS power. Some experts consider that if the United States maintains physical control over the SPS system that it may be considered a dependable source of energy to our nation. Others recommend that U.S. energy reliance on the SPS be limited, looking to other sources for our most essential energy supplies. Similar thoughts occuring to the energy experts of other countries may reduce the acceptability to them of energy from any SPS system under U.S. or other outside control.

However, this dilemma may be less serious than it seems at first sight. There will certainly be more than one satellite -- perhaps one or more for each country that consumes large amounts of energy, and one or more for each group of smaller countries that are willing to combine as neighbors for the common good. Secondly, the technological problem of safeguarding a nation's supply of energy in times of conflict is not unique to the SPS system. Indeed, an attack against a nation's SPS orbital hardware could be considered as much a provocation for war as if that attack had taken place against a hydroelectric dam located within that nation's boundaries. From a broader standpoint, it may be observed that communication satellite services are similarly interruptible by foreign action, and may well be interrupted as a prelude or concomitant to war, and that U.S. oil supplies from abroad may be and have been reduced by foreign action for foreign motives.

Sabotage, either by foreign agents or by radical elements of our society, may constitute another threat to an SPS system, but initial tradeoff studies indicate that the SPS system would probably be no more vulnerable to sabotage than are the present large nuclear-electric generation plants. The vulnerability question deserves a great deal of additional study before valid conclusions may be reached, for the SPS system is unique as a major utility prospect.

Certainly the strategic and political issues also deserve further study. At present, their implications for SPS organizational options are not entirely clear. The overall uncertainty seems to pose a serious barrier or constraint not only to the formation of an international SPS system, whether or not subject to substantial U.S. control, but also to the export of energy from a U.S. system except to close allies of the United States.

A third criterion is cost-effectiveness. This is the comprehensive economic criterion generally used in decision-making. The economically rational choice among a set of options which meet other criteria is the most cost-effective. This does not always mean lowest cost per unit of energy, for other factors contribute to the price acceptability of an energy commodity (roll-in prices are often used to accommodate the exceptions). Certainly the system flexibility and reduced pollution aspects of the SPS are considerations important enough to justify some price differentials, to say nothing of the potential balance of trade benefits.

In conventional cost-benefit analysis, costs and benefits are sometimes defined rather narrowly. The principal SPS benefits can be taken into account without difficulty: contribution to the U.S. energy supply, U.S. energy export potential, and even physical security and reliability (as a risk). On the cost side, however, it is essential to include the major external costs, particularly social and environmental impacts. Unless this is done, cost-effectiveness is too narrow a criterion. When external costs are omitted, the usual method is to treat them as constraints; for example, costs and benefits are measured within the limits of minimum acceptable environmental damage.

A major factor in the cost-effectiveness of an SPS system is the present state of applicable technology and the cost and timing of the necessary research and development. Minor factors include the distribution of economic gains and equitable and non-discriminatory access to the system.

It appears unlikely at this point that the projected huge SPS development costs would ever be charged on a pro rata basis to future SPS energy users (through, perhaps, surcharges to the user utility companies); there is too much historical precedent to the contrary (aircraft, Comsat, nuclear energy). Yet, from our national standpoint, we could do well to urge some of the other energy-hungry nations of the world to join with us in sponsoring the R&D phases of the SPS, thus relieving the United States of the bulk of the economic burden it now faces in pursuing the SPS. Whether such fiscal participation could be arranged, or whether such arrangements might lead to sufficient international bickering to delay or even kill the project, is indeterminable at this point, as is the question of the reaction of Congress to such arrangements. Both Congress and the Office of Management and Budget might be swayed, however, into preferring the formation of an international organization if several foreign nations were to volunteer to contribute sizable sums towards SPS R&D funding on the understanding that they could then become major owners of a future SPS hardware system deployment.

The final criterion is international acceptability and cooperation. This criterion significantly affects all the others, and may be crucial even for an exclusively U.S. system because of the probable need for international agreement on frequency and geosynchronous orbital slot allocations. This factor operates as a constraint on the type of SPS organization that best satisfies the other criteria. On the other hand, the political and psychological consequences of a broad and strong international support would constitute independent benefits of an SPS system, and would also increase other benefits (such as U.S. energy export potential) and hence increase its cost-effectiveness

International acceptability will depend largely on the exact form of the SPS organization, including the nature and extent of multinational participation. The subject is, of course, too large to have been addressed in detail under this first-cut effort, and it requires a great deal of further study; nonetheless, the major issues will now be briefly identified and discussed.

Other countries, especially Communist and Third World countries, are likely to contend that solar energy is a common resource of mankind, not subject to national sovereignty or appropriation. In the past, they have taken this attitude toward outer space (including geosynchronous orbits), seabed resources, and the radio-frequency spectrum. This is a respectable point of view, and deserves to be met seriously, not merely dismissed as self-serving. Nevertheless, it may be pointed out, solar energy differs from mineral and other finite resources in being a flow and not a stock, and for all practical purposes an unlimited resource. In the language of past international resolutions and agreements, it is a sharable and not an exclusive resource.

On the other hand, geosynchronous orbits and the electromagnetic spectrum are, of course, limited. Their limits and problems of equitable and efficient multinational use and access involve many complex technical and institutional factors, and introduce questions which are not likely to be resolved easily or quickly. For example, to what extent would microwave energy transmissions from an SPS interfere with communications satellite or other microwave telecommunications transmissions? What distance or angular separation would be necessary to avoid undue interference? How many geosynchronous slots would be required for SPS use, and in what preferred (optimum) locations? These and many similar questions must be answered with reasonable certainty before international negotiations on the subject can be conducted profitably, and there is every likelihood that international agreements on frequency and geosynchronous orbital slot allocations will have to be consummated prior to any large scale deployment of SPS systems hardware.

Other kinds of questions will significantly affect international acceptability as well as the other factors listed in this report. Social and environmental impacts, for example, must be carefully assessed. A practical balance between U.S. control and multinational participation must be struck, preferably in such a way as to maximize cost-effectiveness and the major benefits to be derived from an SPS system. If all of these factors are not considered carefully, with policies adopted to reasonably satisfy the other nations of the world, international resistance may result which would impede, or even completely prevent, the ultimate deployment of SPS orbital hardware, and even the formation of an international SPS entity may prove impossible.

In this connection, it may be noted that under the 1967 Outer Space Treaty, no portion of outer space may be made subject to a claim of national sovereignty. Geosynchronous orbits are parts of outer space within the meaning of this provision. However, the United States need not assert its sovereignty over geosynchronous orbits in order to use them, since outer space is res communis and thus available for use by all nations, like the high seas. The question nevertheless remains whether the United States is bound by its adherence to the International Telecommunications Union and related agreements to observe ITU allocations of frequencies and geosynchronous orbits for purposes other than international telecommunications. This issue of international law deserves further study.

2. Application of Criteria

In the following table (TABLE I), the tentative criteria were applied to the various types of SPS organizations. A rating of High, Medium, or Low, was given to each organizational option with respect to each criterion. The ratings were recognized as subjective judgments, and the criteria were not weighted. The table is therefore merely illustrative of what might be done by way of comparison, and it is believed that an assessment process of this kind would be useful if carried to a higher stage of refinement and if the criteria, weights, and ratings reflected the objective assessements of a large number of qualified experts.

TABLE I: Ratings of SPS Organizational Options

SPS Organizational Options	Adequate, Timely, and Reliable Contribution to U.S. Energy Supply	Domestic (U.S.) Political Acceptability	Cost Effectiveness	International Acceptability and Cooperation
1. U.N. Agency	Medium	Medium	Low	Medium
2. Independent International Organization				
a. Subject to substantial U.S. control	Medium	High	Medium	Medium
b. Not subject to such control	Low	Low	Low	High
3. Domestic Organization				
U.S Corporation:				
a. Public	Medium	Medium	Medium	Low
b. Non-Profit	Medium	Low	Medium	Low
c. Business	High	Medium	High	Low
d. Public-Private	High	High	High	Medium
U.S. Agency	Medium	High	Medium	Low

From the above Table, the preferred candidates appear to be (in order of preference):

1. A public-private U.S. corporation (Comsat model) with subsequent establishment of the Intelsat equivalent;
2. An international organization independent of the United Nations and subject to substantial control by the U.S. (Intelsat or ESA model);
3. A U.S. domestic business or consortium organization;
4. A U.S. Government Agency or instrumentality (TVA or AEC model).

TABLE II: Characteristics of Leading Candidate Organizational Options

Type of Option	Existing Parallel	Unique Organizational Features	Startup Problems	Time of Formation from Decision Consensus
1. Public-private (U.S.) corporation, with subsequent establishment of international corp.	Comsat/Intelsat	None	International resistance to U.S.-only organization; Some delay on option decision due to differences of opinions & vested interests	Domestic: 6 mos. Intnl.: 1 to 2 yrs.
2. International Organization subject to substantial U.S. control	Intelsat or ESA	None	Some % ownership haggling; some operational control wrangling; foreign concern relative to dependability	2 to 3 years
3. A U.S. corporation or consortium organization	Con-Edison PUD	None	Investment fund availability; Economic viability question; % ownership haggling; political viability question	6 months
4. A U.S. government agency or instrumentality	TVA AEC	None	Private vs. public arguments; political acceptability (Congress) economic viability question	1 year

TABLE II compares the characteristics of the leading candidate options for the prospective SPS organization. It indicates that there are no unique organizational features suggested here, although some could be included if they projected beneficial results. None are really required for the program. Each option has its own particular startup problems, but none of these is an absolute barrier to achieving an SPS organization. Most organizations have problems during their formative period, the small as well as the large, and SPS will not be an exception.

It is difficult to project organization formation time, but once the parties have an agreement in principle, the formation time should not be an unreasonable one. The international option, of course, may be expected to take somewhat longer to develop than the domestic alternatives.

KEY ISSUES AND GENERAL OBSERVATIONS

There are a large number of key questions which will face the future organizers of an operational SPS system, and will strongly affect its structure and operations. Chief among these are the following:

1. International law and international politics

Is the United States bound legally or constrained politically to comply with the preferences of the International Telecommunications Union as to geosynchronous orbit slot location for future SPS hardware deployment? Will the International Court of Justice recognize any future claims made by equatorial states that the sun is being blocked from their lands by an SPS (however insignificant the amount of sun blockage might be)? Might they recognize claims that an SPS which was beaming energy to a receiving antenna located off the coast of Florida was debilitating migratory birds which normally nested (or were killed for food) within their own boundaries during another portion of the year? Might legal claims be made, and even injunctions granted, in international courts to prevent an SPS-deploying nation from "destroying our ozone layer"? Will some perceived risk of space fallout from a large number of deployed SPS structures dampen international enthusiasm for such projects? If the future SPS organizational structure were to be an international entity (i.e., internationally financed and controlled), what is the likelihood that the power output of the first full-scale system would be committed to the United States? What are the principal factors affecting international acceptance of various types of SPS organizations?

2. Operational and strategic issues

Would any single country, like the United States, be trusted by all of the other world powers to exert exclusive control over an operational satellite which might have a power output available in orbit of as much as ten gigawatts? What safeguards and arrangements (if any) would be necessary and sufficient to safeguard the physical security of the SPS

contribution to the U.S. (or any other) national energy supply? Would the "on-off" control of the power output be placed exclusively in the hands of the receiving country? If so, and the system were internationally owned, how would the operators turn off the power in the event that the receiving country refused to pay its power bill? If not, how would the receiver nation be assured of a steady supply of uninterrupted energy? Would the United Nations be a willing custodian of the SPS control switch? How sacrosanct would an SPS orbital installation be considered? That is, would an attack on a U.S.-owned SPS orbital installation be considered an "act of war"?

3. Economic issues

What are the practical economics of the SPS, and how soon can they be convincingly established to the extent that potential investors (national, international, commercial) would have the confidence necessary to commit themselves to a full-scale prototype system? Even if the cost per kilowatt hour of delivered SPS power appears to be appreciably more than that associated with imported oil, would our nation's balance-of-payments benefits derived from an SPS provide such an overriding argument that it would nevertheless be politically adopted, using roll-in prices? Would the system flexibility and reduced pollution aspects of SPS provide similar overriding reasons to adopt the power satellite system? If an international entity were to be selected as a desirable vehicle for SPS, could the other interested countries be induced to contribute funds to the R&D phase of the SPS effort to thus relieve the financial burden of the United States during the critical development cycle of the program?

4. U.S. domestic political issues

What are the principal factors affecting the political feasibility of U.S. participation in various SPS organizational alternatives? Could a large enough number of SPS orbital installations be deployed within a near enough time frame to warrant considering SPS a viable alternative to, say, coal or nuclear power to satisfy today's political needs for establishing it as a realistic solution to our energy crisis, in terms of dedicating national funding, materials, and manpower resources to its accomplishment? Will environmentalists consider SPS in the role of a system which will help save the environment because of the air and water pollution it replaces under an alternative coal system, or will they, instead, concentrate on concerns over added microwave pollution? At whatever future date an SPS organizational entity will be proposed by the Congress or by the President, will our national Zeitgeist cause the legislation to reflect a domestic or international preference, and a commercially-controlled or governmental agency-controlled preference?

It is recognized that the SPS organizational entity may not follow directly in the footsteps of the Comsat/INTELSAT precedence, not only because of strategic differences SPS presents, but because the economic feasibility is not yet established and a single customer-country could likely take all of

the power from a given SPS transmitter. Also, the first entity established may not be a permanent one, or it may later be modified (as was Comsat), or it might be combined with other entities.

As was noted previously, the criteria for the selection of a future SPS organization were established as: adequacy, timeliness, and reliability to serve U.S. national energy needs; U.S. domestic political compatibility; cost-effectiveness; and international acceptability and cooperation. These appeared to embrace all of the likely determining factors for the SPS case.

Besides the timing question of the development cycle and implemental phase of SPS, the most difficult question to address is whether the initial entity should be a domestic or an international organization. Some of the pros and cons of an international organization are as follows:

1. Pros

   International approval of our SPS efforts might be easier to obtain.

   More countries might be likely to buy the product as they would feel more like they were participants.

   Frequency and geosynchronous slot allocations might be easier to obtain from ITU.

   The risk of interruption by foreign or terrorist action might be reduced.

2. Cons

   The U.S. would likely lose control of the organization at the very beginning of the effort.

   There would probably be delays in the initiation, development, and deployment of the operational SPS.

   There would more likely be attendant system and operational inefficiencies (affecting costs and services).

   Runs the risk of reduced level of contribution to the U.S. energy supply.

   Would probably make Congressional approval more difficult to obtain unless assurances were given that U.S. would maintain full operational control.

RECOMMENDATIONS FOR FURTHER STUDY

Further study of the following topics during fiscal year 1979 is recommended in order to answer the key questions previously identified in this White Paper:

1. To what extent would the United States be bound or constrained, in developing and deploying an operational SPS system, by ITU allocations of electromagnetic frequencies and geosynchronous orbital slots?

2. The identification of measures and arrangements necessary and sufficient to safeguard the physical security of energy received from SPS by the United States and other countries.

3. The identification and analysis of the principal factors likely to affect international acceptance of various types of SPS organizations.

4. The identification and analysis of the principal factors likely to affect U.S. participation in various types of SPS organizations.

ACKNOWLEDGMENT

Through the course of this task effort, a number of experts from both the private and public sectors were interviewed for their opinions and projections on the future establishment of an SPS organization. Acknowledgment is hereby given to these experts for giving their time to this project. Their substantive contributions provided a background of varied ideas which aided the writers in predicting downstream responses to SPS-oriented organizational efforts.

The opinions are not individually attributed here, and it is pointed out that some opinions ran contrary to the general consensus and, therefore, the conclusions of this report, but they were nonetheless considered before arriving at the conclusions.

Particular appreciation is expressed to the following for their very useful comments:

Dr. Stephen E. Doyle, Deputy Assistant Administrator for International Affairs, National Aeronautics and Space Administration.

Dr. Burton I. Edelson, Director, Comsat Laboratories and former Staff Member for Communications Satellites, National Aeronautics and Space Council.

Dr. Eileen Galloway, former Staff Member, Senate Committee on Aeronautical and Space Sciences, and Senior Specialist for International Affairs, Congressional Research Service, Library of Congress.

Mr. Jonathan Gibson, Energy Specialist, Sierra Club, Inc.

Mr. Charles C. Hewitt, Executive Director, National Space Institute.

Mr. Hugh Loweth and Mr. Donald Crabill, Office of Management and Budget, Executive Office of the President.

Mr. Alan Ladwig, President, and Mr. Leonard David, Program Director, Forum for the Advancement of Students in Science & Technology, Inc.

Senator Frank E. Moss (Retired), Former Chairman of the Senate Committee on Aeronautical and Space Sciences.

Dr. Russell W. Peterson, Director, Office of Technology Assessment, U.S. Congress, former Governor of Delaware, and former Chairman, Council on Environmental Quality.

Dr. George S. Robinson, Assistant General Counsel, Smithsonian Institution, and authority on space law.

Dr. Charles S. Sheldon II, Research Director, Joint Economic Committee, U.S. Congress, and former Staff Member, National Aeronautics and Space Council.

Mr. Paul L. Sitton, Assistant to the President, National Academy of Sciences.

Dr. Edward C. Welsh, former Executive Secretary, National Aeronautics and Space Council.

Dr. Glen P. Wilson, former Staff Member, Senate Committee on Aeronautical and Space Sciences.

Mr. James E. Wilson and Mr. Philip B. Yeager, Staff Members, House Committee on Science and Technology.

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